PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Commissioner
US Department of Commerce
United States Patent and Trademark Office, PCT
2011 South Clark Place Room CP2/5C24
Arlington, VA 22202
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 13 February 2001 (13.02.01)	
International application No. PCT/KR00/00723	**Applicant's or agent's file reference** P9485-PCT/ST
International filing date (day/month/year) 05 July 2000 (05.07.00)	**Priority date** (day/month/year) 05 July 1999 (05.07.99)
Applicant KIM, Hye-Jeong	

1. The designated Office is hereby notified of its election made:

   [X] in the demand filed with the International Preliminary Examining Authority on:

   11 December 2000 (11.12.00)

   [ ] in a notice effecting later election filed with the International Bureau on:

   _____

2. The election [X] was

   [ ] was not

   made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland**	Authorized officer Zakaria EL KHODARY
Facsimile No.: (41-22) 740.14.35	Telephone No.: (41-22) 338.83.38

특 허 협 력 조
(PATENT COOPERATION TREATY)

발신 : 국제조사기관

수신 :

LEE, Keon Joo

Mihwa Bldg., 110-2, Myongryun-dong 4-ga, Chongno-gu, Seoul 110-524, Republic of Korea

PCT

국제조사보고서 또는 국제조사보고서 부작성 선언서 송부 통지서

(PCT 규칙 44.1)

발송일 (일/월/년)	27 OCTOBER 2000 (27.10.2000)
출원인 또는 대리인 서류참조기호 P9485-PCT/ST	이후의 절차에 대하여는 아래 1. 및 4. 참조
국제출원번호 **PCT/KR00/00723**	국제출원일 (일/월/년) 05 JULY 2000 (05.07.2000)
출원인 SAMSUNG ELECTRONICS CO., LTD. et al	

1. [X] 국제보고서가 작성되어 이를 송부함을 출원인에게 통지합니다.
조약 제19조의 규정에 의한 보정서 및 설명서의 제출:
희망하는 경우 출원인은 국제출원의 청구의 범위를 보정할 수 있습니다.(조약규칙 46):
기간 보정서 제출기간은 통상 국제조사보고서 송부일부터 2월; 보다 자세한 사항은 첨부용지에 기재된 설명(NOTE)을 참조.
제출처 WIPO 국제사무국
34, chemin des Colmbetts
1211 Geneva 20, Switzerland
팩스번호: (41-22) 740 14 35
보다 자세한 지침에 대하여는 첨부되는 용지에 기재된 설명을 참조.

2. [ ] 국제조사보고서가 작성되지 아니할 것이며 조약 제17조(2)(a)의 규정에 의한 선언서가 송부됨을 출원인에게 통지합니다.

3. [ ] 조약규칙 40.2의 규정에 의한 추가수수료 납부에 대한 이의신청과 관련하여 아래 사항을 출원인에게 통지합니다.
[ ] 이의신청 및 이의신청에 대한 결정 통지서를 출원인이 제출한 이의신청 및 이의신청에 대한 결정 통지서의 지정관청에의 송부 신청서와 함께 국제사무국에 송부하였습니다.
[ ] 이의신청에 대한 결정이 아직 이루어지지 않았습니다; 결정이 이루어지는 대로 출원인에게 통지할 것입니다.

4. 추가 조치사항: 출원인은 다음 사항을 상기하여야 합니다.
우선일부터 18월 직후 국제사무국은 국제출원을 공개합니다. 공개를 하지 않거나 또는 연기할 것을 희망하는 경우에는 출원인은 국제공개의 기술적 준비가 완료되기 전에 각각의 경우에 따라 조약규칙 90bis.1 및 90bis.3의 규정에 의한 국제출원 취하서 또는 우선권주장 취하서를 국제사무국에 제출하여야 합니다.
출원인이 우선일부터 30월까지 (일부관청에 대하여는 더 늦을수도 있음) 국내단계의 개시를 연기하고자 하는 경우에는 우선일부터 19월이내에 국제예비심사를 청구하여야 합니다.
출원인은 우선일부터 19월 이내에 국제예비심사청구서에서 또는 후선택시에 선택되지 아니하거나 또는 조약 제2장에 기속되지 아니하여 선택이 불가한 모든 지정관청에 대하여 우선일부터 20월이내에 국내단계를 개시하기 위한 절차를 밟아야 합니다.

ISA/KR의 명칭 및 우편주소 대한민국 특허청 302-701 대한민국 대전광역시 서구 둔산동 정부대전청사	특허청장
팩스 번호 82-42-472-7140	전화번호 82-42-481-5131

서식 PCT/ISA/220 (1998년 7월)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	**FOR FURTHER ACTION**	see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.
P9485-PCT/ST		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/KR00/00723	05 JULY 2000 (05.07.2000)	05 JULY 1999 (05.07.1999)

Applicant

SAMSUNG ELECTRONICS CO., LTD. et al

This International search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 2 sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**
   a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.
   ☐ the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).
   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing:
   ☐ contained in the international application in written form.
   ☐ filed together with the international application in computer readable form.
   ☐ furnished subsequently to this Authority in written form.
   ☐ furnished subsequently to this Authority in computer readable form.
   ☐ the statement that the subsequenlty furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   ☐ the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

2. ☐ **Certain claims were found unsearchable** (See Box I).

3. ☐ **Unity of invention is lacking** (See Box II).

4. With regard to the **title**,
   ☒ the text is approved as submitted by the applicant.
   ☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,
   ☒ the text is approved as submitted by the applicant.
   ☐ the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawing** to be published with the abstract is Figure No. 3, 5
   ☐ as suggested by the applicant.
   ☐ because the applicant failed to suggest a figure.
   ☒ because this figure better characterizes the invention.
   ☐ None of the figures.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR00/00723

A. CLASSIFICATION OF SUBJECT MATTER

IPC7 H04J 11/00,

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimun documentation searched (classification system followed by classification symbols)

KE, JP, US, EP classes as above

Documentation searched other than minimun documentation to the extent that such documents are included in the fileds searched

Korean Patents and applications for inventions since 1975
Korean Utility models and applications for Utility models since 1975

Electronic data base consulted during the intertnational search (name of data base and, where practicable, search trerms used)

NPS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KE 10-99-003705(DAWOO ELECTRIC) 15 JAN. 1999 abstract, col.3 line 26 ~ col. 9 fig 3, 5, 6, 9, 10	1 ~ 8
A	JP 8-79217(VICTOR CO.) 22 MAR. 1996 abstract, fig	1 ~ 8

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevence
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevence; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevence; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
24 OCTOBER 2000 (24.10.2000)	25 OCTOBER 2000 (25.10.2000)
Name and mailing address of the ISA/KR Korean Industrial Property Office Government Complex-Taejon, Dunsan-dong, So-ku, Taejon Metropolitan City 302-701, Republic of Korea Facsimile No. 82-42-472-7140	Authorized officer JEONG, Yong Joo Telephone No. 82-42-481-5674

Form PCT/ISA/210 (second sheet) (July 1998)

COPY FOR IB

10/030232

PATENT COOPERATION TREATY

REC'D 14 NOV 2001

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INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Artcle 36 and Rule 70)

Applicant's or agent's file reference P9485-PCT/ST	**FOR FURTHER ACTION**	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. **PCT/KR00/00723**	International filing date *(day/month/year)* 05 JULY 2000 (05.07.2000)	Priority date *(day/month/year)* 05 JULY 1999 (05.07.1999)

International Patent Classification (IPC) or national classification and IPC

IPC7 H04J 11/00

Applicant

SAMSUNG ELECTRONICS CO., LTD. et al

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 3 sheets, including this cover sheet.

☐ This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

These annexes consist of a total of _____ sheets.

3. This report contains indications relating to the following items:

- I ☒ Basis of the report
- II ☐ Priority
- III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- IV ☐ Lack of unity of invention
- V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- VI ☐ Certain documents cited
- VII ☐ Certain defects in the international application
- VIII ☐ Certain observations on the international application

Date of submission of the demamd	Date of completion of this report
11 DECEMBER 2000 (11.12.2000)	30 OCTOBER 2001 (30.10.2001)

Name and mailing address of the IPEA/KR	Authorized officer
Korean Intellectual Property Office Government Complex-Daejeon, Dunsan-dong, Seo-gu, Daejeon Metropolitan City 302-701, Republic of Korea	JEONG, Yong Joo
Facsimile No. 82-42-472-7140	Telephone No. 82-42-481-5674

Form PCT/IPEA/409 (cover sheet) (July 1998)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International aplication No.
PCT/KR00/00723

I. Basis of the report

1. With regard to the elements of the international application:*

[X] the international application as originally filed

[ ] the description:
pages _____ , as originally filed
pages _____ , filed with the demand
pages _____ , filed with the letter of _____

[ ] the claims:
pages _____ , as originally filed
pages _____ , as amended (together with any statment) under Article 19
pages _____ , filed with the demand
pages _____ , filed with the letter of _____

[ ] the drawings:
pages _____ , as originally filed
pages _____ , filed with the demand
pages _____ , filed with the letter of _____

[ ] the sequence listing part of the description:
pages _____ , as originally filed
pages _____ , filed with the demand
pages _____ , filed with the letter of _____

2. With regard to the language, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.
These elements were available or furnished to this Authority in the following language _____ which is

[ ] the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).

[ ] the language of publication of the international application(under Rule 48.3(b)).

[ ] the language of the translation furnished for the purposes of international preliminary examination(under Rules 55.2 and/or 55.3).

3. With regard to any **nucleotide** and/or amino acid sequence disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

[ ] contained inthe international application in written form.

[ ] filed together with the international application in computer readable form.

[ ] furnished subsequently to this Authority in written form.

[ ] furnished subsequently to this Authority in computer readable form

[ ] The statement that the subsequently furnished written sequence listing does not go beyond the disc losure in the international applicationas as filed has been furinshed.

[ ] The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. [ ] The amendments have resulted in the cancellation of:

[ ] the description, pages _____

[ ] the claims, Nos. _____

[ ] the drawings, sheet _____

5. [ ] This opinion has been drawn as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box(Rule 70.2(c)).**

* *Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this opinion as "originally filed." and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).*

** *Any replacement sheet containing such amendments must be referred to under item I and annexed to this report.*

INTERNATIONAL PRELIMINARY EXAMINATION

International aplication No.
PCT/KR00/00723

V. **Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**

1. Statement

Novelty (N)	Claims	1 - 7	YES
	Claims		NO
Inventive step (IS)	Claims	1 - 7	YES
	Claims		NO
Industrial applicability (IA)	Claims	1 - 7	YES
	Claims		NO

2. Citations and explanations (Rule 70.7)

Documents cited in the International Search Report :
A) KR 99-003705
B) JP 8-079217

The claimed invention relates to an apparatus of compensating for a frequency offset using a pilot symbol for a transmitter in an OFDM/CDMA system including a receiver for performing fine frequency synchronization using a pilot symbol.

The claimed invention is not considered to be anticipated by the patent document cited. None of these documents reveals a receiver for performing fine frequency synchronization using a pilot symbol. KR 99-003705 discloses a pilot symbol insertion for channel equalization.

The invention according to the claims 1-7 is therefore considered to be new, to involve an inventive step and to be industrially applicable.

10/030232

The demand must be filed directly with the competent International Preliminary examining Authority. If two or more Authorities are competent, with the one chosen by the applicant. The full name or two-letter code of that Authority may be indicated by th applicant on th line below:

IPEA/ KR

PCT

CHAPTER II

DEMAND

under Article 31 of the Patent Cooperation Treaty:

The undersigned requests that the international application specified below be the subject of international preliminary examination according to the Patent Cooperation Treaty and hereby elects all eligible States(except where otherwise indicates).

For International Preliminary Examining Authority use only

Identification of IPEA	Date of receipt of DEMAND

Box No. I IDENTIFICATION OF THE INTERNATIONAL APPLICATION		Applicant's or agent's file reference P9485-PCT/ST
International application No. PCT/KR00/00723	International filing date(*day/month/year*) 5 July 2000 (05. 07. 2000)	(earliest)Priority date(*day/month/year*) 5 July 1999 (05. 07. 1999)

Title of invention: APPARATUS OF COMPENSATING FOR FREQUENCY OFFSET USING PILOT SYMBOL IN ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING SYSTEM

Box No. II APPLICANT(S)

Name and address: (*Family name followed by given name: for a legal entity, full official designation. The address must include postal code and name of country.*)	Telephone No.: 82-31-779-7083
SAMSUNG ELECTRONICS CO., LTD. 416, Maetan-dong, Paldal-gu, Suwon-shi, Kyungki-do, 442-370, Republic of Korea	Facsimile No.: 82-31-779-7089 Teleprinter No.:
State(*that is, country*)of nationality: KR	State(*that is, country*)of residence: KR

Name and address: (*Family name followed by given name: for a legal entity, full official designation. The address must include postal code and name of country.*)

Hye-Jeong KIM

Wooseong APT. #228-1506, Sohyon-dong, Puntang-gu, Songnam-shi, 463-050,

Kyonggi-do, Republic of Korea

State(*that is, country*)of nationality: KR	State(*that is, country*)of residence: KR

Name and address: (*Family name followed by given name: for a legal entity, full official designation. The address must include postal code and name of country.*)

State(*that is, country*)of nationality:	State(*that is, country*)of residence:

☐ Further applicants are indicated on a continuation sheet.

International application No
PCT/KR00/00723

Box No. III AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE

The following person is ☒ agent ☐ common representative

and ☒ has been appointed earlier and represents the applicant(s) also for international preliminary examination.

☐ is hereby appointed and any earlier appointment of (an) agent(s)/common representative is hereby revoked

☐ is hereby appointed, specificaly for the procedure before before the International Preliminary Examining Authority, In addition to the agent(s)/common reprsentative appointed earlier.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

LEE Keon-Joo

Mihwa Bldg. 110-2, Myongryun-dong 4-ga, Chongro-gu,
Seoul, 110-524, Republic of Korea

Telephone No.: 82-2-744-0305

Facsimile No.: 82-2-743-5248

Teleprinter No.:

☐ Address for correspondence: Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.

Box No. IV BASIS FOR INTERNATIONAL PRELIMINARY EXAMINATION

Statement concerning amendments: *

1. The applicant wishes the international preliminary examination **to start on the basis of:**

☒ the international application as originally filed

the description	☐	as originally filed
	☐	as amended under Article 34
the claims	☐	as originally filed
	☐	as amended under Article 19(together with any accompanying statement)
	☐	as amended under Article 34
the drawings	☐	as originally filed
	☐	as amended under Article 34

2. ☐ The applicant wishes any amendment to the claims under Article 19 to be considered as reversed.

3. ☐ The applicant wishes the start of the international preliminary examination to be postponed until the expiration of 20 months from the priority date unless the International preliminary examining Authority receives a copy of any amendments made under Article 19 or a notice from the applicant that he does not wish to make such amendments(Rule 69.1(d)). *(This check-box may be marked only where the time limit under Article 19 has not yet expired.)*

* Where no check-box is marked, international preliminary examination will start on the basis of the international application as originally filed or, where a copy of amendments to the claims under Article 19 and/or amendments of the international application under Article 34 are received by the International preliminary examining Authority before it has begun to draw up a written opinion or the international preliminary examination report, as so amended.

Language for the purposes of international preliminary examination: English

☐ which is the language in which the international application was filed.

☐ which is the language of a translation furnished for the purposes of international search.

☒ which is the language of publication of the international application.

☐ which is the language of a translation (to be) furnished for the purposes of international preliminary examination.

Box No. V ELECTION OF STATES

The applicant hereby elects all eligible States *(that is, all States which have been designated and which are bound by Chapter II of the PCT)*

Excluding the following States which the applicant wishes **not to elect:**

International application No.
PCT/KR00/00723

Box No. VI CHECK LIST

The demand is accompanied by the following elements, in the language referred to in Box No. IV, for the purposes of international preliminary examination:			For International Preliminary Examining Authority use only: received	Not received
1. translation of international application	:	sheets	☐	☐
2. amendments under Article 34	:	sheets	☐	☐
3. copy(or, where required, translation)of amendment under Article 19	:	sheets	☐	☐
4. copy(or, where required, translation)of Statement under Article 19	:	sheets	☐	☐
5. letter	:	sheets	☐	☐
6. other*(specify)*	:	sheets	☐	☐

The demand is also accompanied by the item(s) marked below:

1. ☒ fee calculation sheet
2. ☐ separate signed power of attorney
3. ☐ copy of general power of attorney; reference number, if any:
4. ☐ statement explaining lack of signature
5. ☐ nucleotide and or amino acid sequence listing in computer readable form
6. ☐ other*(specify)*:

Box No. VII SIGNATURE OF APPLICANT, AGENT OR COMMON REPRESENTATIVE

Next to each signature, indicate the name of th person signing and the capacity in which the person sings(if such capacity is not obous from reading the demand).

LEE Keon-Joo

Agent for the applicant

For International Preliminary Examining Authority use only

1. Date of actual receipt of DEMAND:
2. Adjusted date of receipt of demand due to CORRECTIONS under Rule 60.1(b)
3. ☐ The date of receipt of the demand is AFTER the expiration of 19 months from the priority date and item 4 or 5, below, does not apply. ☐ The applicant has been informed accordingly.
4. ☐ The date of receipt of the demand is WITHIN the period of 19 months from the priority date as extended by virtue of Rule 80.5
5. ☐ Although the date of receipt of the demand is after the experation of 19 months from the priority date, the delay in arrival is EXCUSED pursuant to rule 82

For International Bureau use only

Demand received from IPEA on:

PCT

CHAPTER II

FEE CALCULATION SHEET

Annex to the Demand for international preliminary examination

International application No.	PCT/KR00/00723
Applicant's or agent's file reference	P9485-PCT/ST

For International Preliminary Examining Authority use only

Date stamp of the IPEA

Applicant

SAMSUNG ELECTRONICS CO. LTD.

Calculation of prescribed fees

1. Preliminary examination fee	₩ 150,000	P
2. Handling fee *(Applicants from certain States are entiltled to a reduction of 75% of the handling fee. Where the applicant is (or all applicants are) so entitled the amount to be entered at H is 25% of the handlig fee.)*	₩ 166,400	H
3. Total of prescribed fees Add the amounts entered at P and H and enter total in the TOTAL box	₩ 316,400	TOTAL

Mode of Payment

☐	authorization to caarge deposit accout with the IPEA (see below)	☒	cash
☐	cheque	☐	revenue stamps
☐	postal money order	☐	coupons
☐	bank draft	☐	others*(specify)*:

Deposit Account Authorization *(this mode of payment may not be available at all IPEAs)*

The IPEA/ _____ ☐ is hereby authorized to charge the total fees indicated above to my deposit account.

☐ *(this check-box may be marked only if the conditions for deposit accounts of the IPEA so permit)* is hereby authorized to charge any deficiency or credit any overpayment in the total fees indicated above to my deposit account.

Deposit Account Number	Date*(day/month/year)*	signature

See Notes to the demand form

PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:
LEE, Keon Joo

Mihwa Bldg., 110-2, Myongryun-dong 4-ga, Chongno-gu, Seoul
110-524, Republic of Korea

PCT

NOTIFICATION OF TRANSMITTAL OF INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Rule 71.1)

Date of mailing *(day/month/year)*	05 NOVEMBER 2001 (05.11.2001)
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Applicant

SAMSUNG ELECTRONICS CO., LTD. et al

1. The applicant is hereby notified that International Preliminary Examining Authority transmits here with the international preliminary examination report and its annexes, if any, established on the international application.

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report(but not of any annexes) and will transmit such translation to those Offices.

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The applicant must enter the national phase before each elected office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices) (Article 39(1)) (see also the reminder sent by the International Bureau with Form PCT/IB/301).

Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

For further details in the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

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From the INTERNATIONAL BUREAU

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NOTICE INFORMING THE APPLICANT OF THE COMMUNICATION OF THE INTERNATIONAL APPLICATION TO THE DESIGNATED OFFICES

(PCT Rule 47.1(c), first sentence)

To:
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Applicant's or agent's file reference P9485-PCT/ST	**IMPORTANT NOTICE**
International application No. PCT/KR00/00723	**International filing date** (day/month/year) 05 July 2000 (05.07.00)
Priority date (day/month/year) 05 July 1999 (05.07.99)	
Applicant SAMSUNG ELECTRONICS CO., LTD. et al	

1. Notice is hereby given that the International Bureau has communicated, as provided in Article 20, the international application to the following designated Offices on the date indicated above as the date of mailing of this Notice:
   US

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2. The following designated Offices have waived the requirement for such a communication at this time:
   CN,EP,JP

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3. Enclosed with this Notice is a copy of the international application as published by the International Bureau on
   11 January 2001 (11.01.01) under No. WO 01/03347

REMINDER REGARDING CHAPTER II (Article 31(2)(a) and Rule 54.2)

If the applicant wishes to postpone entry into the national phase until 30 months (or later in some Offices) from the priority date, a **demand for international preliminary examination** must be filed with the competent International Preliminary Examining Authority before the expiration of 19 months from the priority date.

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If the applicant wishes to proceed with the international application in the **national phase**, he must, within 20 months or 30 months, or later in some Offices, perform the acts referred to therein before each designated or elected Office.

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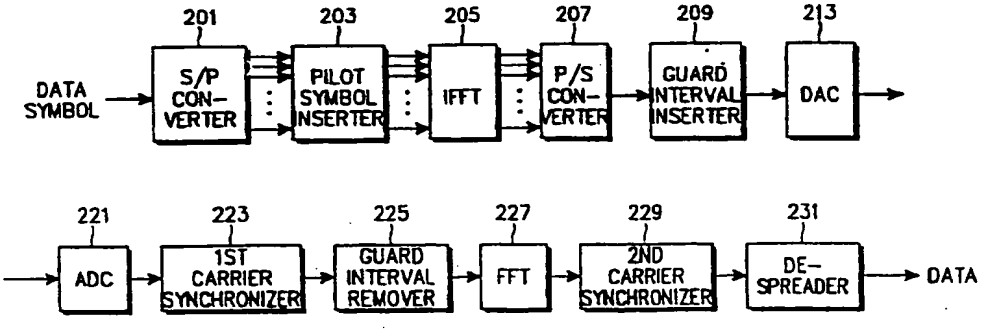


(57) Abstract: An apparatus of compensating for a frequency offset using a guard interval and a pilot symbol, which are inserted at a transmitter, in an OFDM (Orthogonal Frequency Division Multiplexing) system. The OFDM system receives an OFDM signal in which a pilot symbol is inserted in data of a frame unit at regular intervals and a guard interval is inserted in a data symbol. In the system, a first carrier synchronizer receives a data symbol stream obtained by converting the OFDM signal to digital data, and detects a guard interval of each data symbol, to compensate for a coarse frequency offset. A fast Fourier transform part OFDM-demodulates a signal output from the first carrier synchronizer. A second carrier synchronizer detects the pilot symbol from the demodulated data symbol stream to compensate for a fine frequency error.

WO 01/03347 A1

APPARATUS OF COMPENSATING FOR FREQUENCY OFFSET USING PILOT SYMBOL IN AN ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to a frequency offset compensation apparatus for an OFDM/CDMA (Orthogonal Frequency Division Multiplexing/Code Division Multiple Access) system, and in particular, to a frequency offset compensation apparatus which compensates for a frequency offset (or frequency error) using a guard interval and a pilot symbol.

2. Description of the Related Art

As the types of the recent multimedia services are diversified, it is necessary to transmit data at high speed. In addition, as the user's demand for construction of a wireless network increases, a wireless asynchronous transmission mode (hereinafter, referred to as "WATM") market is expanded. Thus, every country forms various organizations for WATM standardization to expedite implementation of the WATM technology. For implementation of such a high-speed data transmission technology, active researches are being carried out on a method for using the orthogonal frequency division multiplexing (hereinafter, referred to as "OFDM") technology in implementing the high-speed data transmission. In the OFDM technology, data is transmitted on a plurality of subcarriers after inverse fast Fourier transform (IFFT), and the transmitted subcarriers are converted to the original data in an OFDM receiver through fast Fourier transform (FFT).

FIG. 1 illustrates a structure of a general OFDM/CDMA system. With reference to FIG. 1, a description will be made of the structure and operation of a transceiver in the OFDM/CDMA system.

First, the structure of a transmitter will be described. A spreader 101 spreads data symbol streams to be transmitted by multiplying the data symbol streams by a code of an N rate in a data symbol unit. Herein, N data bits obtained by multiplying the data symbol by the code of N rate will be referred to as "data samples". The N data samples spread from the data symbol are parallelized by a serial-to-parallel (S/P) converter 103

and then, input to a pilot sample inserter 105. The pilot sample inserter 105 receives the N data samples in parallel, punctures the received data samples at regular intervals, and then inserts pilot data samples as shown in FIG. 2, and the pilot sample-inserted data symbol is provided to an inverse fast Fourier transform (IFFT) section 107. The IFFT 107 receives in parallel the pilot sample-inserted data samples in the data symbol unit and performs inverse fast Fourier transform on the received data samples. In the following description, the IFFT-transformed data output from the IFFT 107 will be referred to as "OFDM symbol". The OFDM symbol is also comprised of N data samples. The OFDM symbol output from the IFFT 107 is input to a guard interval inserter 109. The guard interval inserter 109 copies a part of the rear end of the received OFDM symbol and inserts it in the front of the OFDM symbol. The guard interval-inserted OFDM symbol is converted to an analog OFDM symbol by a digital-to-analog converter (DAC) 111 and the converted analog OFDM symbol is transmitted after up-conversion.

Next, a receiver down-converts the analog signal transmitted from the transmitter. Because of the inaccuracy of an oscillator used during the down-conversion, the baseband signal includes a frequency offset. The analog signal is converted to a digital OFDM symbol by an analog-to-digital converter (ADC) 121 and then, applied to a guard interval remover 123. The guard interval remover 123 frame-synchronizes the OFDM symbol output from the ADC 121, and after frame synchronization, removes the guard interval included in the OFDM symbol, the guard interval-removed OFDM symbol being applied to a fast Fourier transform (FFT) section 125. The FFT 125 FFT-transforms the OFDM symbol output from the guard interval remover 123 and outputs a data symbol. At this point, since a signal is obtained which is shifted by the frequency offset included during the down-conversion, it is difficult to recover the original data. Particularly, in an OFDM/CDMA system where a desired signal is carried at each frequency band, the frequency offset should be correctly estimated and compensated for to recover the original signal. To compensate for the frequency offset, a carrier synchronizer 127 detects a pilot sample from the data symbol output from the FFT 125, and performs carrier synchronization using the detected pilot sample. A despreader 129 despreads the data symbol output from the FFT 125, which was spread into N data samples, and outputs the original data symbol.

The FFT 125 generally recovers the frequency offset using the FFT characteristics shown in Equation (1) below.

$$X[n]W_N^{K_0 n} \leftrightarrow X[k-k_0](W_N = e^{\frac{-j2\pi}{N}}) \quad \ldots\ldots (1)$$

where X[n] is an input signal in a time domain, which is input to the FFT, $W_N^{K_0 n}$ is an offset term, and $X[k-k_0]$ denotes a received signal with a frequency offset, which is shifted by k_0 from the transmission signal during down-conversion.

FIG. 2 illustrates a data structure used in the general OFDM/CDMA system, which shows that the pilot data samples are inserted after puncturing N data samples for each data symbol in a specific pattern. Since the pilot data samples are inserted in a specific pattern, Equation (1) is calculated using the pilot data samples and the frequency offset is compensated for by calculating a shift amount k_0 of the data calculated by Equation (1).

In an ideal system, since the pilot samples received as shown in Equation (1) are received in a position shifted by k_0 samples from the original reference sample position, it is possible to calculate the frequency offset k_0 by estimating the shifted value using a correlator. However, in the OFDM/CDMA system, use of the above pilot samples causes such performance degradation as an increase of over 2 times in a data rate, complication of a receiving stage for compensating for the frequency offset, and an increase in a noise level, so that it is difficult to use the pilot samples.

A non-ideal system has the more serious problems. The factors affecting the IFFT-transformed signal include a timing error, a common phase error (CPE) and the noises. In the receiver, a timing error n_ϵ in a time domain, after passing the FFT stage, are expressed by the product of the original signal in the frequency domain and an exponential term. This ultimately affects even the pilot sample value, so that an increase of this value may cause considerable performance degradation of the correlator. Therefore, in the OFDM/CDMA system, it is difficult for the conventional frequency offset compensation method to detect a correct frequency offset value.

SUMMARY OF THE INVENTION

It is, therefore, an object of the present invention to provide a transmitter which inserts pilots (or pilot symbols) of a symbol unit at regular intervals when transmitting a

data symbol steam, to enable exact frequency offset correction at a receiver.

It is another object of the present invention to provide a frequency offset compensation apparatus which compensates twice for a frequency offset using a guard interval and a pilot symbol included in received frame data in which pilot symbols are inserted at regular intervals.

To achieve the above object, a transmitter for an OFDM system includes a modulator for OFDM-modulating a received data symbol, a guard interval inserter for inserting a guard interval in the OFDM-modulated data symbol, a pilot symbol inserter for inserting a pilot symbol in the data of frame unit output from the guard interval inserter at regular intervals, and an analog-to-digital converter for converting the data output from the pilot symbol inserter to an analog signal.

To achieve another object, a receiver for an OFDM system, which receives an OFDM signal for which a pilot symbol is inserted in data of a frame unit at regular intervals and a guard interval is inserted in a data symbol, includes a first carrier synchronizer for receiving a data symbol stream obtained by converting the OFDM signal to digital data and compensating for an approximate frequency offset by detecting the guard interval of each data symbol, a fast Fourier transform section for OFDM-demodulating the signal output from the first carrier synchronizer, and a second carrier synchronizer for compensating for a fine frequency offset by detecting the pilot symbol from the demodulated data symbol stream.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the present invention will become more apparent from the following detailed description when taken in conjunction with the accompanying drawings in which:

FIG. 1 is a diagram illustrating a structure of a general OFDM/CDMA system;

FIG. 2 is a diagram illustrating a data structure using pilot samples in a general OFDM/CDMA system;

FIG. 3 is a diagram illustrating a structure of a transmitter in an OFDM/CDMA system according to an embodiment of the present invention;

FIG. 4A is a diagram illustrating pilot symbol-inserted frame structure in an OFDM/CDMA system according to an embodiment of the present invention;

FIG. 4B is a diagram illustrating a guard interval-inserted frame structure in an OFDM/CDMA system according to an embodiment of the present invention;

FIG. 5 is a diagram illustrating a structure of a receiver in an OFDM/CDMA system according to an embodiment of the present invention;

FIG. 6 is a diagram illustrating a detailed structure of the first carrier synchronize of FIG. 5; and

FIG. 7 is a diagram illustrating a detailed structure of the second carrier synchronizer of FIG. 5.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

A preferred embodiment of the present invention will be described herein below with reference to the accompanying drawings. In the following description, well-known functions or constructions are not described in detail since they would obscure the invention in unnecessary detail.

In an exemplary embodiment of the present invention, a guard interval and a pilot symbol are used to estimate a frequency offset in such actual states as timing error, common phase error and noises. A structure of a transmitter for inserting the guard interval and the pilot symbol before transmission will be described below with reference to FIG. 3.

A serial-to-parallel (S/P) converter 201 receives in series a data symbol, which is spread with a code of length N and comprised of N data samples, and outputs the N data samples in parallel. A pilot symbol inserter 203 receives in parallel the N data samples from the S/P converter 201, and inserts pilot symbols in a frame in a specific pattern before transmission. The pilot symbol inserter 203 can be comprised of means (not shown) for generating the pilot symbol and switching means (now shown) for switching the data symbol and the pilot symbol according to a specific pattern. The switching means can be comprised of a multiplexer. The pilot symbol inserter 203 can also be positioned in a preceding stage of the S/P converter 201. An inverse fast Fourier transform (IFFT) section 205 receives in parallel the N data samples output from the pilot symbol inserter 203, performs inverse fast Fourier transform on the received data samples, and outputs the IFFT-transformed OFDM symbol to a parallel-to-serial (P/S) converter 207. The IFFT-transformed OFDM symbol is comprised of N data samples. Since the N data samples of the OFDM symbol are OFDM-modulated in the data

symbol unit, those are different from the N data samples before the IFFT operation. The P/S converter 207 serializes the IFFT-transformed N data samples and outputs them to a guard interval inserter 209. The guard interval inserter 209 copies a part of the rear end of the OFDM symbol output from the P/S converter 207, and inserts it in the front of the data symbol. In the following description, it will be assumed that the number of data samples in the guard interval is N (the number of data samples) × 1/2.

A digital-to-analog converter (DAC) 213 converts the OFDM symbol output from the guard interval inserter 209 and then up-converts the converted OFDM symbol before transmission.

FIG. 4A illustrates a pilot symbol-inserted frame structure in an OFDM/CDMA system according to an embodiment of the present invention, wherein the hatched symbols #0 and #5 are the pilot symbols, and the pilot symbols are inserted at intervals of 4 data symbols. The pilot symbols can also be inserted in one frame at regular intervals or inserted at regular intervals without frame separation.

FIG. 4B illustrates a guard interval-inserted frame structure output from the guard interval inserter 209 of FIG. 3, in an OFDM/CDMA system according to an embodiment of the present invention.

In FIG. 4B, for the guard interval of each OFDM symbol, a part of the rear end of the corresponding OFDM symbol is copied and inserted in the front of the OFDM symbol. In the embodiment of the present invention, a length of the guard interval is determined as 1/2 the number N of the data samples.

FIG. 5 illustrates a structure of a receiver in an OFDM/CDMA system according to an embodiment of the present invention.

In actual circumstances, the receiver of the OFDM/CDMA system has the frequency offset, the common phase error, the noises and the timing error. The signals received in the actual circumstances should be modeled. As illustrated in FIG. 3, if it is assumed that the signal at the input end of the IFFT 205 in the transmitter of the OFDM/CDMA system is $X_m(k)$ and the signal passed the IFFT 205, in which the guard interval is not inserted yet, is $X_m[n]$, a signal FFT-transformed by the receiver after removing $y'_m[n]$ and the guard interval from an analog-to-digital converted signal will

be defined as $Y'_m[k]$ in the following description.

If a frequency offset per symbol is k_e [Hz/symbol], then a frequency offset per sample is k_e/N [Hz/sample] and a frequency offset $k_m[n]$ of an n^{th} sample of an m^{th} symbol is expressed by Equation (2) below.

$$k_m[n] = \frac{k_e}{N} m\{N+G\} + \frac{k_e}{N} n \quad \ldots\ldots (2)$$

where G denotes the number of samples in the guard interval.

In the receiver, a signal $y_m[n]$ including the frequency offset, the common phase error and the noises is expressed by Equation (3) below, in which for convenience, the number of samples is given from –G to N-1.

$$\begin{aligned} y_m[n] &= X_m[n] \cdot e^{j2\pi k_m[n]} \cdot e^{jP_e} + W_m[n] \\ &= X_m[n] \cdot e^{\frac{j2\pi k_e\{m(N+G)+n\}}{N}} \cdot e^{jP_e} + W_m[n] \\ &= X_m[n] \cdot e^{j2\pi k_e \frac{n}{N}} \cdot e^{\frac{j2\pi k_e m(N+G)}{N}} \cdot e^{jP_e} + W_m[n] \quad \ldots\ldots (3) \end{aligned}$$

where P_e denotes the common phase error and $W_m[n]$ denotes AWGN (Additive White Gaussian Noise) of the m^{th} symbol.

Now, the structure and operation of the receiver will be described with reference o FIG. 5. An analog-to-digital converter (ADC) 221 down-converts the analog signal transmitted from the transmitter and converts the down-converted analog signal to a digital OFDM symbol. In the following description, the signal output from the ADC 221 will be defined as $y'_m[n]$. A first carrier synchronizer 223 is a carrier synchronizer which uses the guard interval. The first carrier synchronizer 223 receives the OFDM symbol output from the ADC 221, detects a guard interval G of the FODM symbol and G data samples (hereinafter, referred to as copied data samples) at the rear end of the data symbol used to insert the guard interval, and performs frequency synchronization by compensating for the frequency offset of the OFDM symbol output from the ADC 221 using the guard interval and the data samples copied to generate the guard interval. In the embodiment of the present invention, the number G of the data

samples in the guard interval is 1/2 the number N of the data samples of the data symbol. If a signal of the guard interval, i.e., the guard interval comprised of the G data samples inserted in the front of the m^{th} OFDM symbol is defined as $G_m[n]$ and the last G data samples of the OFDM symbol, i.e., the data samples copied to create the guard interval is defined as $R_m[n]$, then $G_m[n]$ and $R_m[n]$ can be expressed by Equation (4) below.

$$G_m[n] = y_m[n-G]\cdot e^{\frac{j2\pi k_e[n-G]}{N}}\cdot e^{\frac{j2\pi k_e[n+G]}{N}}\cdot e^{jP_e} + W_m[n-G]$$
$$R_m[n] = y_m[n+N-G]\cdot e^{\frac{j2\pi k_e[n+N-G]}{N}}\cdot e^{\frac{j2\pi k_e[n+N+G]}{N}}\cdot e^{jP_e} + W_m[n+N-G] \quad \ldots (4)$$

A detailed description will be made of a carrier synchronizing operation using the guard interval of the first carrier synchronizer 223 in accordance with Equations (2) to (4). The first carrier synchronizer 223 detects phases of the $G_m[n]$ and $R_m[n]$, and calculates a phase difference between the detected phases of $G_m[n]$ and $R_m[n]$. The phase difference between $G_m[n]$ and Rm[n] is expressed by Equation (5) below.

$$\angle G_m[n] = \angle X_m[n-G] + \frac{2\pi k_e[n-G]}{N} + \frac{2\pi k_e m[N+G]}{N} + P_e + \angle W_m[n-G]$$
$$\angle R_m[n] = \angle X_m[n+N-G] + \frac{2\pi k_e[n+N-G]}{N} + \frac{2\pi k_e m[N+G]}{N} + P_e + \angle W_m[n+N-G]$$
$$\angle R_m[n] - \angle G_m[n] = \angle X_m[n+N-G] - \angle X_m[n-G] + \frac{2\pi k_e[n+N-G]}{N} - \frac{2\pi k_e[n-G]}{N} + \angle W_m[n+N-G] - W_m[n-G]$$
$$= 2\pi k_e + \angle W_m[n+N-G] - \angle W_m[n-G] \quad \ldots\ldots (5)$$

In Equation (5), $X_m[n+N+G]$ and $X_m[n-G]$ are the identical signal, so that the phase difference is '0'.

When the phase difference between $G_m[n]$ and $R_m[n]$ is calculated from Equation (5), the first carrier synchronizer 223 calculates an average value of the phase difference using Equation (6) below. The first carrier synchronizer 223 performs carrier synchronization by approximately compensating for the frequency offset of the data input from the ADC 221 based on the calculated average value.

$$k_e = \frac{avg\{\angle R_m[n] - \angle G_m[n]\}}{2\pi} \quad \ldots\ldots (6)$$

Here, if there exists a timing error, there is a case where Equations (2) to (6) are not correct. If the timing error such as an FFT start point detection error and a timing frequency offset is n_e, a signal $y'_m[n]$ including the timing error can be expressed by Equation (7) below.

$$\begin{aligned} y'_m &= y_m[n - n_e] \\ &= X_m[n - n_e] \cdot e^{\frac{j\pi pik_e[n-n_e]}{N}} \cdot e^{\frac{j2\pi k_e m[n+G]}{N}} \cdot e^{jP_e} + W_m[n - n_e] \quad \ldots\ldots (7) \end{aligned}$$

Here, $y'_m[n]$ includes data samples of the $(m-1)^{th}$ OFDM symbol or the $(m+1)^{th}$ OFDM symbol according to the value of n_e. On the above assumption, the phase difference of the respective samples is calculated by Equation (8) below.

$$\begin{aligned} \angle R_m[n] - \angle G_m[n] &= \angle X_m[n + N - G - n_e] - \angle X_m[n - G - n_e] \\ &+ \frac{2\pi k_e[n + N - G - n_e]}{N} - \frac{2\pi k_e[n - G - n_e]}{N} + \angle W_m[n + N - G - n_e] - W_m[n - G - n_e] \\ &= 2\pi k_e + \angle W_m[n + N - G - n_e] - \angle W_m[n - G - n_e] \quad \ldots\ldots (8) \end{aligned}$$

In Equation (8), $G_m[n]$ and $R_m[n]$ have the values shifted by n_e from their original values, so that the range of $X_m[n+N+G-n_e]$ and $X_m[n-G-n_e]$ becomes $n=n_e$, n_e+1, .., G-1, and n=0, 1, 2, .., $G-n_e-1$ for the negative number. Hence, if an approximate range of the timing error of the system is known, the frequency offset is calculated in the interval from which the range is excluded. For example, if the maximum timing error does not exceed 'a', the frequency offset can be estimated using Equation (9) below by calculating the phase difference in the interval of n=a, a+1, .., G-a-2, G-a-1, and calculating the average value.

$$k_e = \frac{avg[\angle R_m[n] - \angle G_m[n]]}{2\pi} \quad \ldots\ldots (9)$$

Equations (2) to (9) are used when the first carrier synchronizer 223 performs carrier synchronization by estimating the approximate frequency offset. The first carrier synchronizer 223 has the better performance when the used guard interval becomes

longer and the timing error of the system has the narrower range. Otherwise, the frequency offset measuring interval becomes shorter, so that the first carrier synchronizer is more affected by the noises and has a difficulty in correctly measuring the frequency offset. After the approximate carrier synchronization, a guard interval remover 225 removes the guard interval from the received data output from the first carrier synchronizer 223 and outputs the guard interval-removed data to a fast Fourier transform (FFT) section 227. The FFT 227 receives the guard interval-removed OFDM symbol, performs the FFT operation on the received OFDM symbol and outputs the original data symbol.

A second carrier synchronizer 229 receives the data symbol FFT-transformed by the FFT 227 and performs fine carrier synchronization on the received data symbol. Specifically, the second carrier synchronizer 229 detects the pilot symbol of the symbol unit from the data symbol stream, and calculates a phase of the detected pilot symbol. The second carrier synchronizer 229 estimates the fine frequency offset by calculating a phase difference between the calculated phase of the pilot symbol and a known phase of a pilot symbol. After estimation of the fine frequency offset, the second carrier synchronizer 229 performs fine carrier synchronization by compensating for the estimated fine frequency offset.

An operation of the second carrier synchronizer 229 will be mathematically described below. For the data symbol output from the FFT 227, a frequency offset according to the FFT characteristics is a shift timing error of the signal and is converted to a variation of the phase. This can be expressed by Equation (10) below.

$$y'_m[k] = X_m[k-k_i]\cdot e^{\frac{j2\pi[k-k_i]n_s}{N}}\cdot e^{\frac{j2\pi k_i m(N+G)}{N}}\cdot e^{jP_s} + W_m[k-k_i]$$
$$= X_m[k-k_i]\cdot e^{\frac{j2\pi kn_s}{N}}\cdot e^{-\frac{j2\pi k_i n_s}{N}}\cdot e^{-\frac{j2\pi k_i m(N+G)}{N}}\cdot W_m[k-k_i] \quad \ldots\ldots\ldots (10)$$

where k_i denotes the fine frequency offset.

If only the pilot symbol is detected from the received data, the range of m is 0, l-1, 2l-1, 3l-1, ..., where l denotes a period for inserting the pilot symbol of the symbol unit.

The phase difference of the received pilot symbol is calculated by Equation (11) below.

$$\angle y'_m[k] = \angle X_m[k-k_i] + \frac{2\pi n_e}{N}k - \frac{2\pi n_e k_i}{N} + \frac{2\pi k_i m[N+G]}{N} + P_e + \angle W_m[k-k_i] \quad \ldots\ldots (11)$$

In Equation (11), the second term is expressed in terms of a specific variation of the phase according to an index k, the next three terms are expressed in terms of a constant phase offset, and the last term is expressed in terms of a variation of the phase. If the transmitter continuously uses the same pilot symbol and the time error, the common phase error and the frequency offset are identical during the pilot symbol insertion period, then a phase difference between consecutive two pilot symbols $Y_{mpi}'(k)$ and Y_{mpi+1} is calculated by

$$\begin{aligned} diff_{phase} &= \angle y'_{m\pi+1}[k] - \angle y'_{m\pi}[k] \\ &= \angle X_{m\pi+1}[k-k_i] - \angle X_{m\pi}[k-k_i] + \frac{2\pi k_i m_{\pi+1}[N+G]}{N} - \frac{2\pi k_i m_\pi [N+G]}{N} \\ &\quad + \angle W_{m_{\pi+1}}[k-k_i] - \angle W_{m_\pi}[k-k_i] \quad \ldots\ldots\ldots (12) \end{aligned}$$

If the transmitter uses the same pilot symbol as stated above, the first term and the second term have the same value. Hence, Equation (12) can be expressed by Equation (13) below.

$$\begin{aligned} diff_{phase} &= [m_{\pi+1} - m_\pi]\frac{2\pi k_i[N+G]}{N} + \angle W_{m_{\pi+1}}[k-k_i] - \angle W_{m_\pi}[k-k_i] \\ &= I\frac{2\pi k_i[N+G]}{N} + \angle W_{m_{\pi+1}}[k-k_i] - \angle W_{m_\pi}[k-k_i] \quad \ldots\ldots\ldots (13) \end{aligned}$$

In Equation (13), the first term is expressed in terms of a constant for N samples of one pilot symbol, and the other terms are expressed in terms of a variation due to the noises. Hence, by calculating an average value of the phase differences for N samples, it is possible to obtain the constant of the first term, from which the influence of the noises is almost removed. From this value, it is possible to calculate a fine frequency offset k_i in accordance with Equation (14) below.

$$k_e = \frac{avg\ diff_{phase} \times N}{2\pi[N+G] \times I} \quad \ldots\ldots\ldots (14)$$

After calculating the fine frequency offset using Equation (14), the second carrier synchronizer 229 performs carrier synchronization by compensating for a frequency offset of the OFDM symbol based on the calculated frequency offset, and provides its output to a despreader 231. The despreader 231 despreads the fine frequency-synchronized received data.

The detailed structure of the first carrier synchronizer 223 and the second carrier synchronizer 229 will be described with reference to FIGS. 6 and 7. Specifically, FIG. 6 illustrates the detailed structure of the first carrier synchronizer of FIG. 5, and FIG. 7 illustrates the detailed structure of the second carrier synchronizer of FIG. 5.

In FIG. 6, a guard interval detector 301 receives the OFDM symbol stream including the respective guard intervals, output from the ADC 221 of FIG. 5, detects the respective guard intervals $G_m[n]$ included in the OFDM symbol stream, and calculates phases of the respective guard intervals $G_m[n]$. A copied sample detector 303 receives the OFDM symbol stream, detects data samples (hereinafter, referred to as "copied data samples") of the OFDM symbol copied to create the guard intervals $G_m[n]$ to be detected, and calculates phases of the copied data samples. In Equations (2) to (9), the copied data samples are indicated by $R_m[n]$. A phase difference detector 305 calculates phase differences between the data samples of the guard intervals $G_m[n]$ output from the guard interval detector 301 and the copied data samples $R_m[n]$ output from the copied sample detector 303, and outputs the detected phase differences to an averager 307. The averager 307 calculates an approximate frequency offset by averaging the phase differences output from the phase difference detector 305 in a unit of G (=R), and outputs an approximate frequency offset compensation signal to a first frequency offset compensator 309. The first frequency offset compensator 309 receives the OFDM symbol stream including the guard intervals output from the ADC 221, and compensates for the approximate frequency offset of the OFDM symbol stream according to the approximate frequency offset compensation signal output from the averager 307.

In FIG. 7, a pilot symbol detector 311 receives IFFT-transformed received data output from the FFT 227, and detects a pilot symbol included in the received data. The

pilot symbol output from the pilot symbol detector 311 is applied to a delay 312 and a phase difference detector 313. The delay 312 buffers the detected pilot symbol, delays the buffered pilot symbol by the pilot symbol insertion period, and then outputs the delayed pilot symbol to a phase difference detector 313. The phase difference detector 313 receives the pilot symbol detected by the pilot symbol detector 311 and the pilot symbol delayed by the symbol insertion period from the detected pilot symbol, output from the delay 312, calculates phase differences between the corresponding samples of the two pilot symbols, and outputs the calculated phase differences to an averager 314. The averager 314 estimates the fine frequency offset by calculating an average value of the phase differences in the pilot symbol period. After estimation of the fine frequency offset, the averager 314 outputs a fine frequency offset compensation signal for the fine frequency offset to a second offset compensator 315. The second offset compensator 315 receives the FFT-transformed received data from the FFT 327, and compensates for a fine frequency offset of the received data according to the fine frequency offset compensation signal output from the averager 314.

As described above, the invention can compensate for a frequency offset even in a situation where the timing error is not compensated for, and increase the accuracy of frequency offset estimation by removing the influence of the variation due to the noises.

WHAT IS CLAIMED IS:

1. An apparatus of compensating for a frequency offset using a pilot symbol for a transmitter in an OFDM/CDMA (Orthogonal Frequency Division Multiplexing/Code Division Multiple Access) system including a receiver for performing fine frequency synchronization using a pilot symbol, comprising:

a pilot symbol inserter for receiving a spread data symbol stream and inserting a pilot symbol in a symbol unit according to a predetermined pattern.

2. An apparatus of compensating for a frequency offset using a pilot symbol for a transmitter in an OFDM/CDMA system including a receiver for performing fine frequency synchronization using a pilot symbol, comprising:

a pilot symbol inserter for receiving a spread data symbol steam, and inserting a pilot symbol at intervals of predetermined data symbols;

a serial-to-parallel (S/P) converter for receiving the pilot symbol-inserted data symbol stream, and outputting N data samples of a symbol unit in parallel;

an inverse fast Fourier transform (IFFT) section for performing an IFFT operation on the N data samples;

a parallel-to-serial (P/S) converter for serializing the IFFT-transformed N data samples and outputting an OFDM symbol; and

a guard interval inserter for copying a part of the N data samples of the OFDM symbol and inserting the copied data samples in the front of the OFDM symbol.

3. An apparatus of compensating a frequency offset using a pilot symbol for a receiver in an OFDM/CDMA system including a transmitter for inserting a pilot symbol in a data symbol of frame unit in a specific pattern before transmission, comprising:

a carrier synchronizer for compensating for a fine frequency offset using the pilot symbol inserted in the specific pattern out of the IFFT-transformed data symbol stream.

4. The apparatus as claimed in claim 3, wherein the carrier synchronizer comprises:

a pilot symbol detector for detecting a pilot symbol from an OFDM-demodulated data symbol stream;

a delay for delaying the detected pilot symbol by a predetermined time;

a phase difference detector for detecting a phase of the pilot symbol output from the pilot symbol detector and a phase of the delayed pilot symbol output from the delay, and calculating a phase difference between the two pilot symbols;

an averager for calculating a fine frequency offset by averaging the phase differences in a frame unit and outputting a second frequency offset compensation signal according to the fine frequency offset; and

a second frequency offset compensator for compensating for a fine frequency offset of the demodulated data symbol according to the second frequency offset compensation signal.

5. An apparatus of compensating for a frequency offset using a pilot symbol for a receiver in an OFDM/CDMA system including a transmitter for inserting a pilot symbol in a data symbol stream of a frame unit in a specific pattern before transmission, comprising:

a first carrier synchronizer for receiving an OFDM symbol stream including received guard intervals and performing approximate frequency synchronization on the received OFDM symbol stream using the guard interval;

a guard interval remover for removing the guard intervals from the OFMD symbol streams after performing frequency synchronization;

a fast Fourier transform (FFT) section for performing an FFT operation on the guard interval-removed OFDM symbol and outputting the data symbol; and

a second carrier synchronizer for compensating for a fine frequency offset using the pilot symbol inserted in the data symbol stream in the specific pattern.

6. The apparatus as claimed in claim 5, wherein the first carrier synchronizer comprises:

a guard interval detector for detecting a guard interval from the OFDM symbol stream;

a copied sample detector for detecting data samples copied to create the detected guard interval, from the OFDM symbol stream;

a phase difference detector for calculating a phase of the data samples of the detected guard interval and a phase of the copied data samples, and calculating a phase difference between the two data samples;

an averager for calculating a frequency error by averaging the phase differences output from the phase difference detector in the frame unit, and outputting a first frequency offset compensation signal according to the frequency offset; and

a first frequency offset compensator for compensating for a frequency offset of the OFDM symbol according to the first frequency offset compensation signal.

7. The apparatus as claimed in claim 5, wherein the second carrier synchronizer comprises:

a pilot symbol detector for detecting the pilot symbol from the data symbol stream;

a delay for delaying the pilot symbol by a pilot symbol insertion period;

a phase difference detector for detecting a phase of a pilot symbol output from the pilot symbol detector and a phase of the delayed pilot symbol output from the delay, and calculating a phase difference between the two pilot symbols;

an average for calculating a fine frequency offset by averaging the phase differences received in the frame unit, and outputting a second frequency offset compensation signal according to the fine frequency offset; and

a second frequency offset compensator for compensating a fine frequency error of the demodulated data symbol according to the second frequency offset compensation signal.

8. The apparatus as claimed in claim 7, wherein the fine frequency offset is calculated by

$$k_e = \frac{avg\ diff_{phase} \times N}{2\pi[N+G] \times I}.$$

FIG. 1

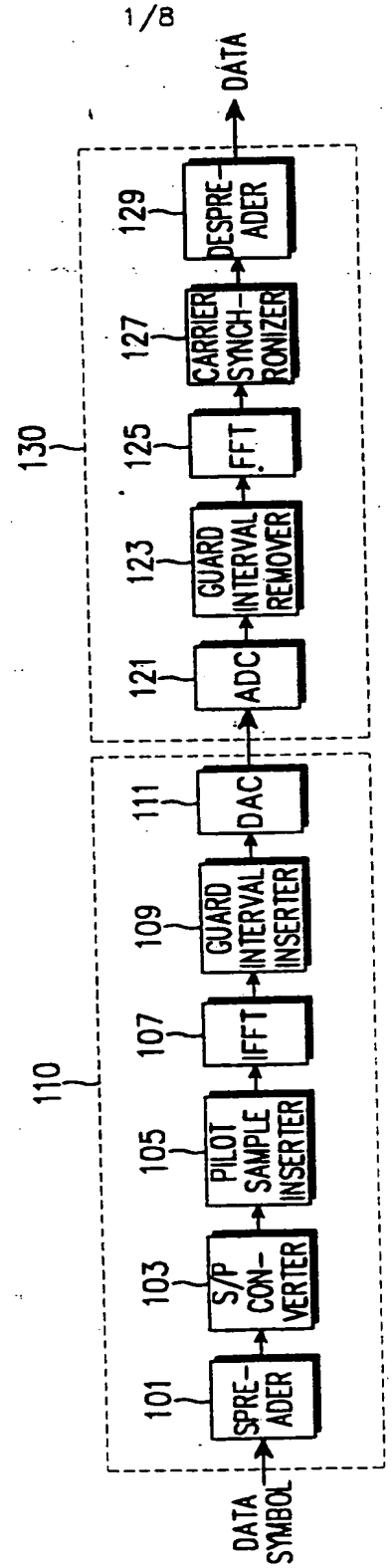

DATA SYMBOL
101
SPRE-ADER
103
S/P CON-VERTER
105
PILOT SAMPLE INSERTER
107
IFFT
109
GUARD INTERVAL INSERTER
111
DAC
110
121
ADC
123
GUARD INTERVAL REMOVER
125
FFT
127
CARRIER SYNCH-RONIZER
129
DESPRE-ADER
130
DATA

FIG. 2

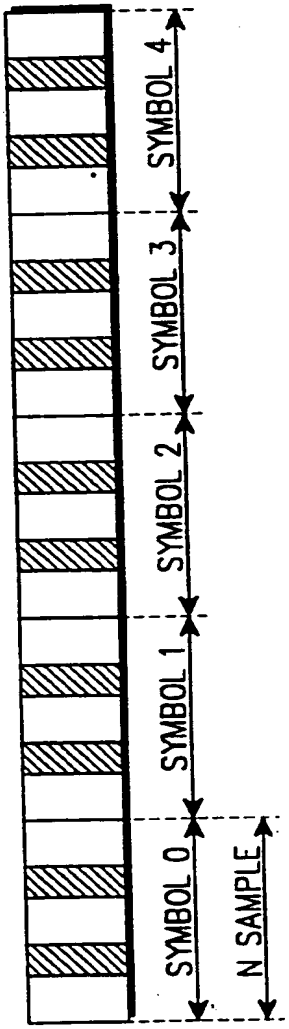


FIG. 3

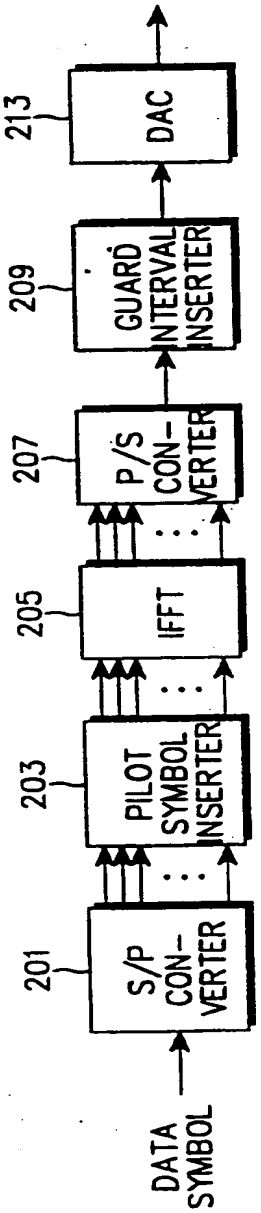

DATA SYMBOL
201
S/P CON-VERTER
203
PILOT SYMBOL INSERTER
205
IFFT
207
P/S CON-VERTER
209
GUARD INTERVAL INSERTER
213
DAC

FIG. 4A

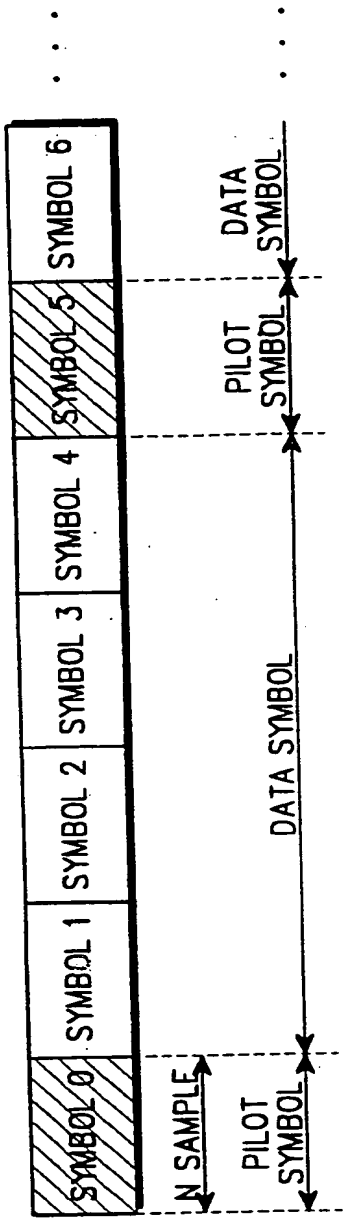

SYMBOL 6
SYMBOL 5
SYMBOL 4
SYMBOL 3
SYMBOL 2
SYMBOL 1
SYMBOL 0
DATA SYMBOL
PILOT SYMBOL
DATA SYMBOL
N SAMPLE
PILOT SYMBOL

FIG. 4B

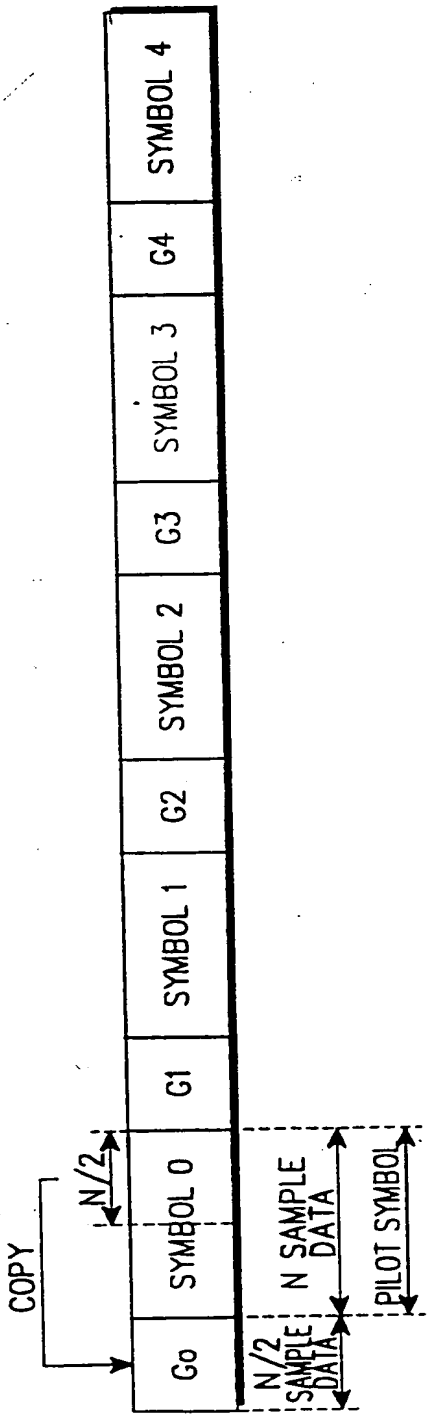

SYMBOL 4
G4
SYMBOL 3
G3
SYMBOL 2
G2
SYMBOL 1
G1
SYMBOL 0
Go
N/2
COPY
N/2 SAMPLE DATA
N SAMPLE DATA
PILOT SYMBOL

FIG. 5

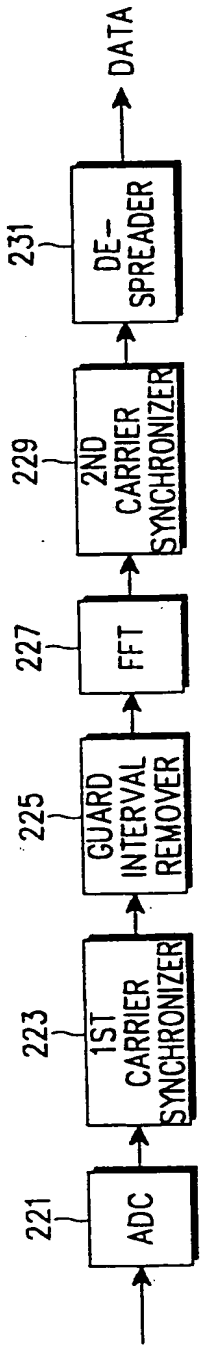

221
ADC
223
1ST CARRIER SYNCHRONIZER
225
GUARD INTERVAL REMOVER
227
FFT
229
2ND CARRIER SYNCHRONIZER
231
DE-SPREADER
DATA

FIG. 6

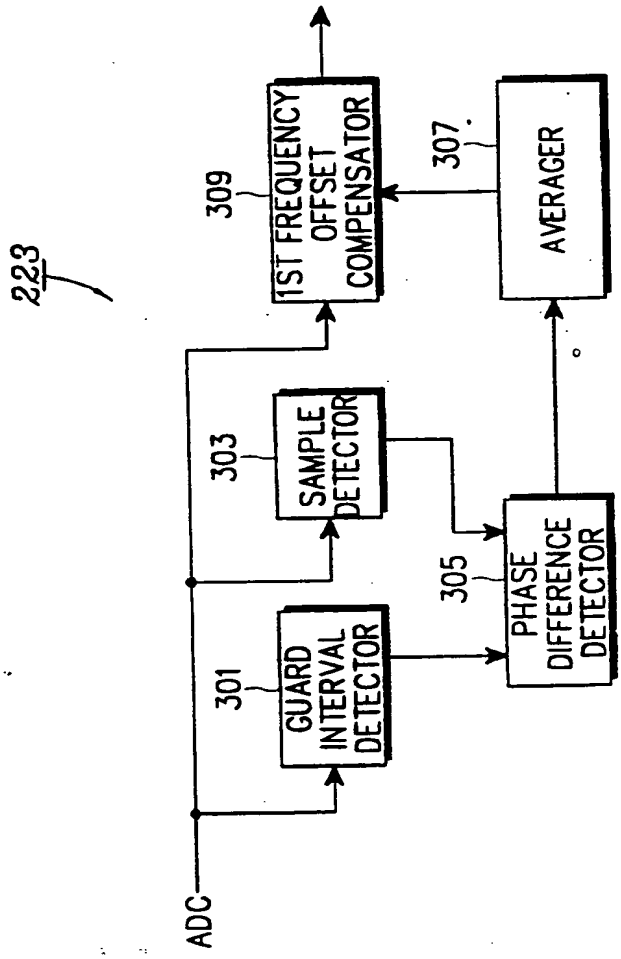
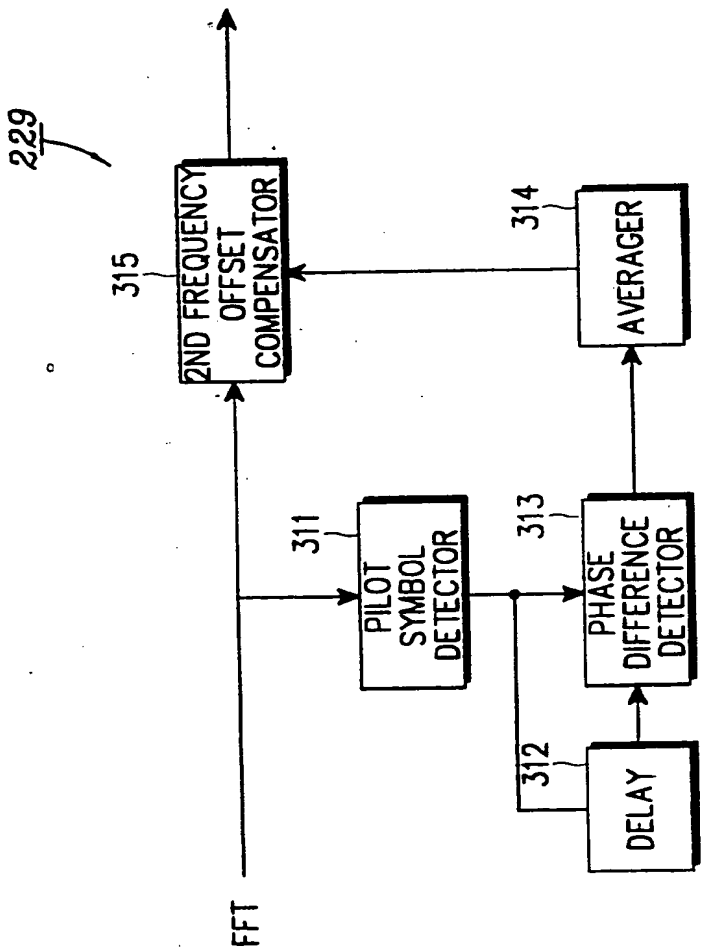

223
309
1ST FREQUENCY OFFSET COMPENSATOR
307
AVERAGER
303
SAMPLE DETECTOR
305
PHASE DIFFERENCE DETECTOR
301
GUARD INTERVAL DETECTOR
ADC

FIG. 7


229
2ND FREQUENCY OFFSET COMPENSATOR
315
AVERAGER
314
PILOT SYMBOL DETECTOR
311
PHASE DIFFERENCE DETECTOR
313
DELAY
312
FFT

PCT REQUEST

Original (for SUBMISSION) - printed on 05.07.2000 04:52:35 PM

0 0-1	For receiving Office use only International Application No.	
0-2	International Filing Date	
0-3	Name of receiving Office and "PCT International Application"	
0-4 0-4-1	Form - PCT/RO/101 PCT Request Prepared using	PCT-EASY Version 2.90 (updated 10.05.2000)
0-5	Petition The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty	
0-6	Receiving Office (specified by the applicant)	Korean Industrial Property Office (RO/KR)
0-7	Applicant's or agent's file reference	P9485-PCT/ST
I	Title of invention	APPARATUS OF COMPENSATING FOR FREQUENCY OFFSET USING PILOT SYMBOL IN ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING SYSTEM
II II-1 II-2 II-4 II-5 II-6 II-7 II-8 II-9 II-10	Applicant This person is: Applicant for Name Address: State of nationality State of residence Telephone No. Facsimile No. e-mail	 applicant only all designated States except US SAMSUNG ELECTRONICS CO., LTD. 416, Maetan-dong, Paldal-gu, Suwon-shi 442-370 Kyungki-do Republic of Korea KR KR 82-31-779-7083 82-31-779-7089 xhpark@samsung.co.kr
III-1 III-1-1 III-1-2 III-1-4 III-1-5 III-1-6 III-1-7	Applicant and/or inventor This person is: Applicant for Name (LAST, First) Address: State of nationality State of residence	 applicant and inventor US only KIM, Hye-Jeong Wooseong APT. #228-1506, Sohyon-dong, Puntang-gu, Songnam-shi 463-050 Kyonggi-do Republic of Korea KR KR

PCT REQUEST

P9485-PCT/ST

Original (for **SUBMISSION**) - printed on 05.07.2000 04:52:35 PM

IV-1	**Agent or common representative; or address for correspondence** The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as:	agent
IV-1-1	Name (LAST, First)	LEE, Keon-Joo
IV-1-2	Address:	Mihwa Bldg. 110-2, Myongryun-dong 4-ga, Chongro-gu 110-524 Seoul Republic of Korea
IV-1-3	Telephone No.	82-2-744-0305
IV-1-4	Facsimile No.	82-2-743-5248
IV-1-5	e-mail	kjlp@unitel.co.kr
V	**Designation of States**	
V-1	Regional Patent (other kinds of protection or treatment, if any, are specified between parentheses after the designation(s) concerned)	EP: AT BE CH&LI CY DE DK ES FI FR GB GR IE IT LU MC NL PT SE and any other State which is a Contracting State of the European Patent Convention and of the PCT
V-2	National Patent (other kinds of protection or treatment, if any, are specified between parentheses after the designation(s) concerned)	CN JP US
V-5	**Precautionary Designation Statement** In addition to the designations made under items V-1, V-2 and V-3, the applicant also makes under Rule 4.9(b) all designations which would be permitted under the PCT except any designation(s) of the State(s) indicated under item V-6 below. The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit.	
V-6	**Exclusion(s) from precautionary designations**	NONE
VI-1	**Priority claim of earlier national application**	
VI-1-1	Filing date	05 July 1999 (05.07.1999)
VI-1-2	Number	1999-26862
VI-1-3	Country	KR
VII-1	**International Searching Authority Chosen**	Korean Industrial Property Office (KIPO) (ISA/KR)

VIII	**Check list**	number of sheets	electronic file(s) attached
VIII-1	Request	3	-
VIII-2	Description	17	-
VIII-3	Claims	5	-
VIII-4	Abstract	1	9485-abstract.txt
VIII-5	Drawings	8	-
VIII-7	TOTAL	34	

PCT REQUEST

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	Accompanying items	paper document(s) attached	electronic file(s) attached
VIII-8	Fee calculation sheet	✓	-
VIII-9	Separate signed power of attorney	✓	-
VIII-10	Copy of general power of attorney	✓	-
VIII-16	PCT-EASY diskette	-	diskette
VIII-18	**Figure of the drawings which should accompany the abstract**	5	
VIII-19	**Language of filing of the international application**	Korean	
IX-1	**Signature of applicant or agent**		
IX-1-1	Name (LAST, First)	LEE, Keon-Joo	

FOR RECEIVING OFFICE USE ONLY

10-1	**Date of actual receipt of the purported international application**	
10-2	**Drawings:**	
10-2-1	Received	
10-2-2	Not received	
10-3	**Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application**	
10-4	**Date of timely receipt of the required corrections under PCT Article 11(2)**	
10-5	**International Searching Authority**	ISA/KR
10-6	**Transmittal of search copy delayed until search fee is paid**	

FOR INTERNATIONAL BUREAU USE ONLY

11-1	**Date of receipt of the record copy by the International Bureau**	

PCT (ANNEX - FEE CALCULATION SHEET)

P9485-PCT/ST

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(This sheet is not part of and does not count as a sheet of the international application)

0 0-1	**For receiving Office use only** International Application No.			
0-2	Date stamp of the receiving Office			
0-4 0-4-1	**Form - PCT/RO/101 (Annex)** **PCT Fee Calculation Sheet** Prepared using	PCT-EASY Version 2.90 (updated 10.05.2000)		
0-9	**Applicant's or agent's file reference**	P9485-PCT/ST		
2	**Applicant**	SAMSUNG ELECTRONICS CO., LTD., et al.		
12	**Calculation of prescribed fees**	fee amount/multiplier	total amounts (KRW)	
12-1	Transmittal fee T	⇨	45,000	
12-2	Search fee S	⇨	150,000	
12-3	International fee Basic fee (first 30 sheets) b1	465,800		
12-4	Remaining sheets	4		
12-5	Additional amount (X)	10,700		
12-6	Total additional amount b2	42,800		
12-7	b1 + b2 = B	508,600		
12-8	Designation fees Number of designations contained in international application $_c$	4		
12-9	Number of designation fees payable (maximum 8)	4		
12-10	Amount of designation fee (X)	100,300		
12-11	Total designation fees D	401,200		
12-12	PCT-EASY fee reduction R	-143,300		
12-13	Total International fee (B+D-R) I	⇨	766,500	
12-17	**TOTAL FEES PAYABLE (T+S+I+P)**	⇨	961,500	
12-19	**Mode of payment**	cash		

VALIDATION LOG AND REMARKS

13-2-1	**Validation messages** **Request**	Green? A translation of the international application into English will have to be prepared under the responsibility of the ISA selected.
		Green? Please note that the entire request (including the title of invention) must be in English
		Green? The title of the invention shall be short and precise. Please verify.

PCT (ANNEX - FEE CALCULATION SHEET) P9485-PCT/ST

Original (for SUBMISSION) - printed on 05.07.2000 04:52:35 PM

13-2-2	Validation messages States	Green? More designations could be made. The following States have not been designated: AP:(GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW); EA:(AM, AZ, BY, KG, KZ, MD, RU, TJ, TM); OA:(BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG); AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, LI, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW. Please verify.
13-2-6	Validation messages Contents	Green? Priority 1. The priority document is not enclosed. (The applicant must furnish it within 16 months from the earliest priority date claimed)
		Green? Reference number for attached copy of general power of attorney not indicated.
13-2-7	Validation messages Fees	Green? Please confirm that fee schedule utilized is the latest available
13-2-10	Validation messages For receiving Office/International Bureau use only	Green? Verify electronic data for consistency against printed form.